

p̄ Note #415

REPORT ON FURUKAWA COAX #2

6 December 1984

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INTRODUCTION :

This report contains the results of measurements performed on sample coax #2 from the Furukawa Cable Co. of Japan. Time domain reflectometer (TDR) and RLC measurements were made at room temperature and superconducting. Network analyzer measurements of S11 and S21 were made for the superconducting coax.

COAX CHARACTERISTICS :

Production No. CH-60058
Piece No. 2

| <u>TEST ITEM</u> | <u>SPECIFICATION</u> | <u>TEST RESULT</u> |
|---------------------------------------|-----------------------------|--------------------|
| Inner cond. diam. | 0.460 +/- 0.001 mm | 0.458 mm |
| Dielectric diam. | 1.57 +/- 0.01 mm | 1.577 mm |
| Inner diam. of outer conductor | 1.60 +/- 0.01 mm | 1.608 mm |
| Polyethylene terphthalate film | 0.025 mm Thick 9 mm Wide | 0.023 mm 9.0 mm |
| Overall diam. | 1.85 +/- 0.1 mm | 1.93 mm |
| Characteristic impedance at -196 C | ---- | 53.6 Ohms |

(The above information was furnished by the manufacturer.)

TDR MEASUREMENTS :

The following figures show TDR measurements of the coax at room temperature and at superconducting temperature. The center horizontal line in each photo is the 50 Ohm reference level and each vertical division is 2 Ohms. The horizontal axis in each picture is 2 nSec per division.

Note the discontinuities at the junction to the sample cable in the photos of the warm test and those at the junctions at the top of the dewar and at the coax sample in the superconducting tests.

The TDR photos show that the warm cable has an impedance between 55 and 56 ohms. Note that the TDR trace is pulled by the level change. This is due to the TDR electronics.

For the superconducting cable the impedance at both ends is about 52 Ohms +/- 0.5 Ohm allowing for ripple and calibration error.

*

RLC MEASUREMENTS :

Measurements of resistance, inductance and capacitance of the sample were made at room temperature and superconducting. The results are shown in the following table.

| | Measured | Expected |
|---|--------------------|------------|
| | ----- | ----- |
| Warm: Resistance - inner cond. | 47.4 Ohms | 43.95 Ohms |
| | outer cond. | 12.66 Ohms |
| Capacitance - | 38.67 nF | 38.40 nF |
| | dissipation factor | 0.0250 |
| Inductance - | 240.0 uH | 128.1 uH |
| | Q | 0.025 |
| Superconducting: (feedlines subtracted) | | |
| Resistance - inner cond. | 0.0 Ohms | 0 Ohms |
| | outer cond. | 0.0 Ohms |
| Capacitance - | 38.97 nF | 39.60 nF |
| | dissipation factor | 0 |
| Inductance - | 106.8 uH | 104.10 uH |
| | Q (feed included) | 1.12 |
| Calculated characteristic impedance | 52.35 Ohms | 51.27 Ohms |

Assuming Z=50 Ohms, epsilon=2.1, L=420 m and coax dimensions as measured by manufacturer.

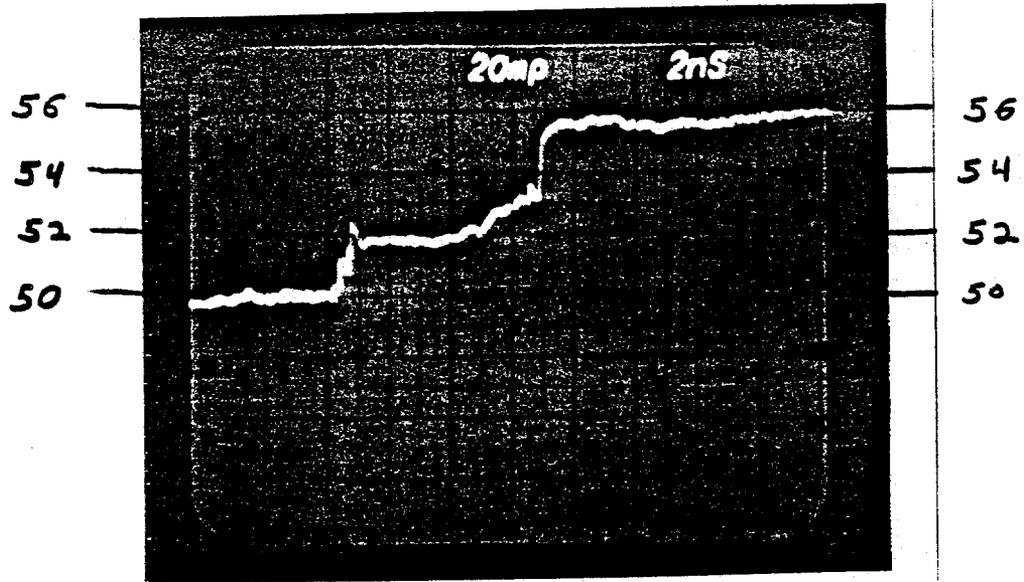
* Measured using a General Radio Company Type 1656 Impedance Bridge.

TDR MEASUREMENTS COAX #2

WARM

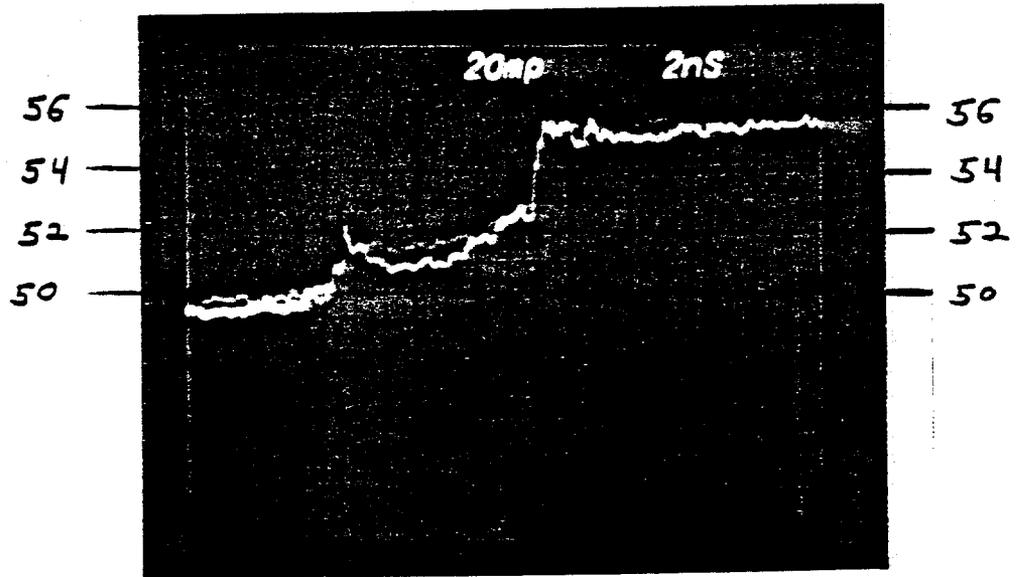
5 DEC 84

5310



← → FEED LINE | → SUPER LINE NEAR END

5310



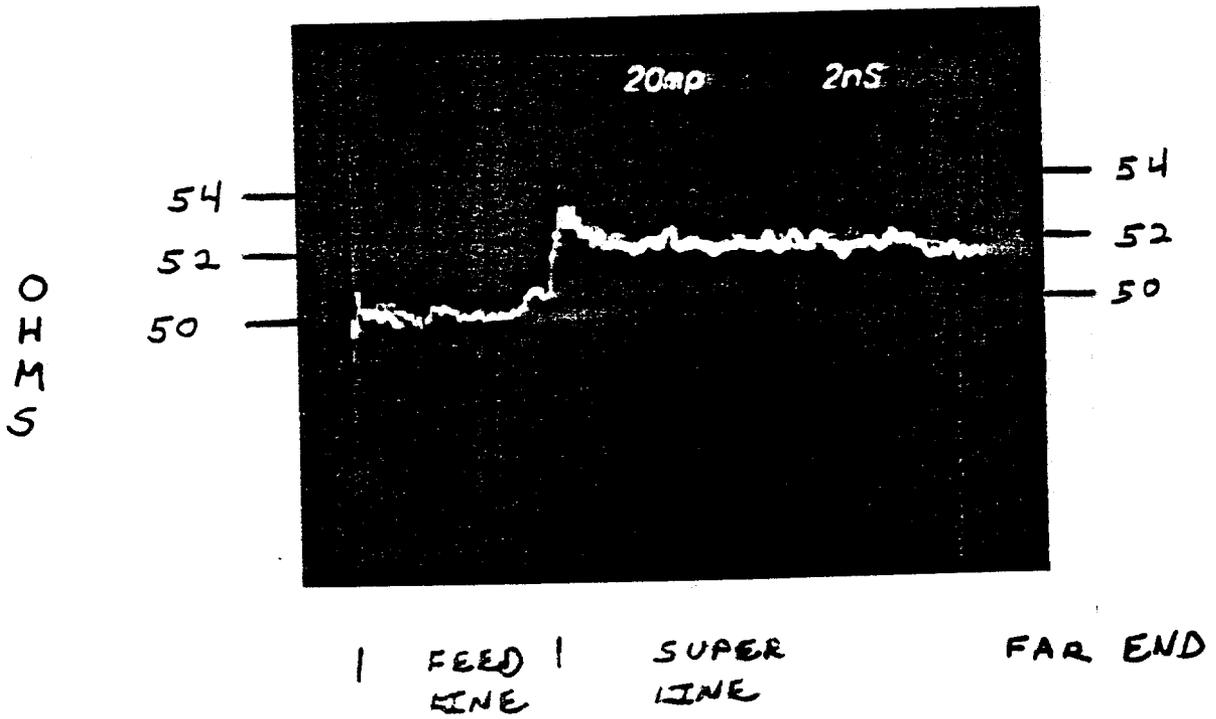
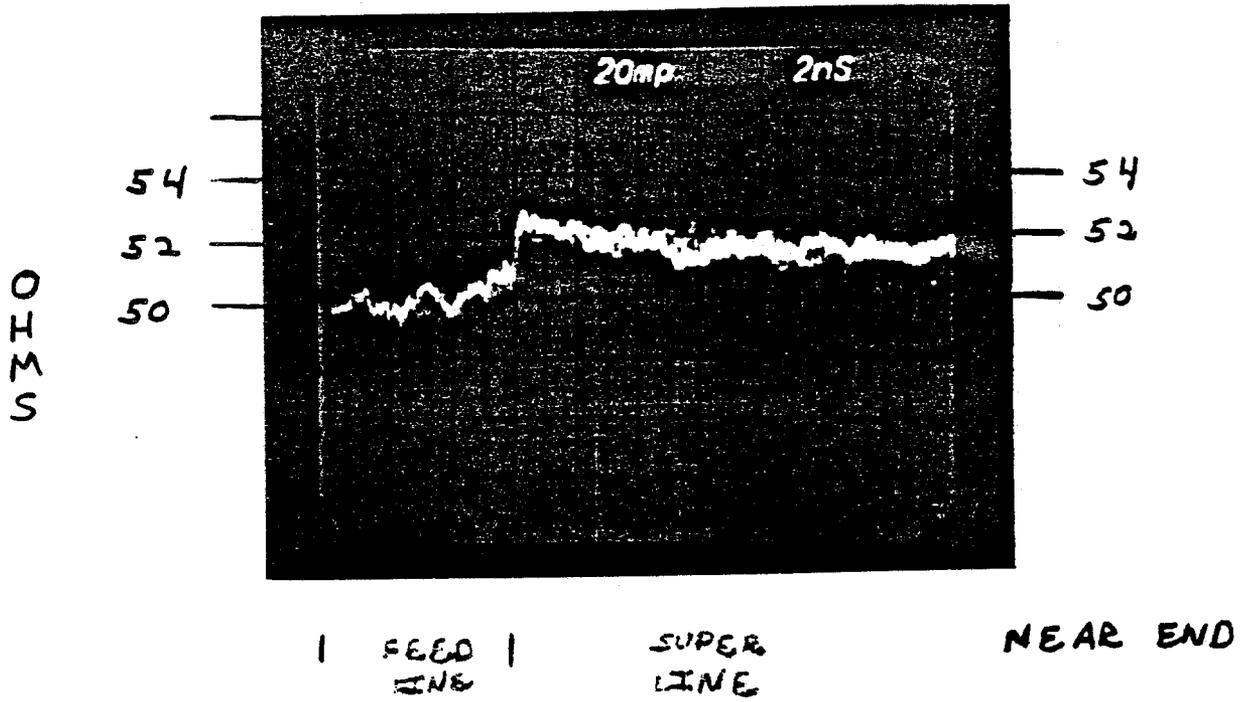
← → FEED LINE | → SUPER LINE FAR END

TDR MEASUREMENTS

COAX #2

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SUPERCONDUCTING



S-PARAMETER MEASUREMENTS :

The following plots are for the superconducting coax #1 as measured by a Hewlett-Packard 8410C automated network analyzer. Shown are S11 and S21 with feedlines subtracted for the following ranges:

| NAME | START (MHz) | STOP (MHz) | STEP (MHz) |
|---------|----------------|---------------|---------------|
| FURAX21 | 500 | 4000 | 10 |
| FURAX22 | 4000 | 8000 | 10 |
| FURAX23 | 800 | 1500 | 2 |
| FURAX24 | 1500 | 2200 | 2 |
| FURAX25 | 1500 | 3000 | 5 |
| FURAX26 | 3000 | 4500 | 5 |
| FURAX27 | 1400 | 1500 | 0.25 |
| FURAX28 | 1500 | 1600 | 0.25 |
| FURAX29 | 1490 | 1500 | 0.025 |
| FURAX30 | 1500 | 1510 | 0.025 |
| FURAX31 | 1500 | 1501 | 0.0025 |

The plots of S11 show the periodic nature of the coax characteristics, particularly FURAX31 which has the greatest resolution. The plots of S21 have the effect of the feedlines subtracted out.

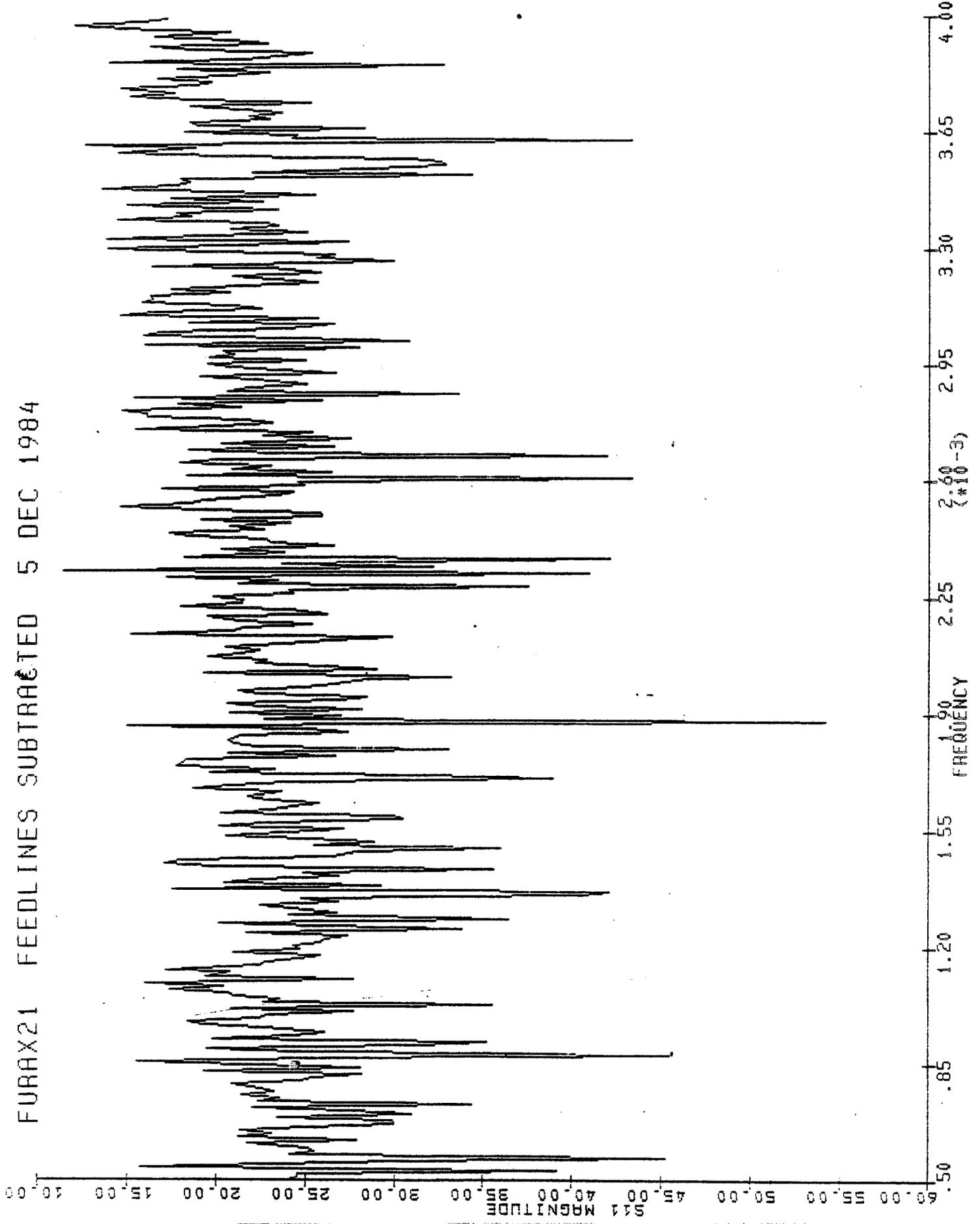
Areas of note are in the S21 plot FURAX22 which shows a resonance at 5.5 GHz and the plot of FURAX23 which shows two spikes below 1 GHz. Plots of S21 for FURAX21 and FURAX22 have the formula for coax loss according to Hoshiko(1) plotted also. The equation is

$$\text{Attenuation} = 0.5 f + 0.05 f^2 \quad \text{dB/KM}$$

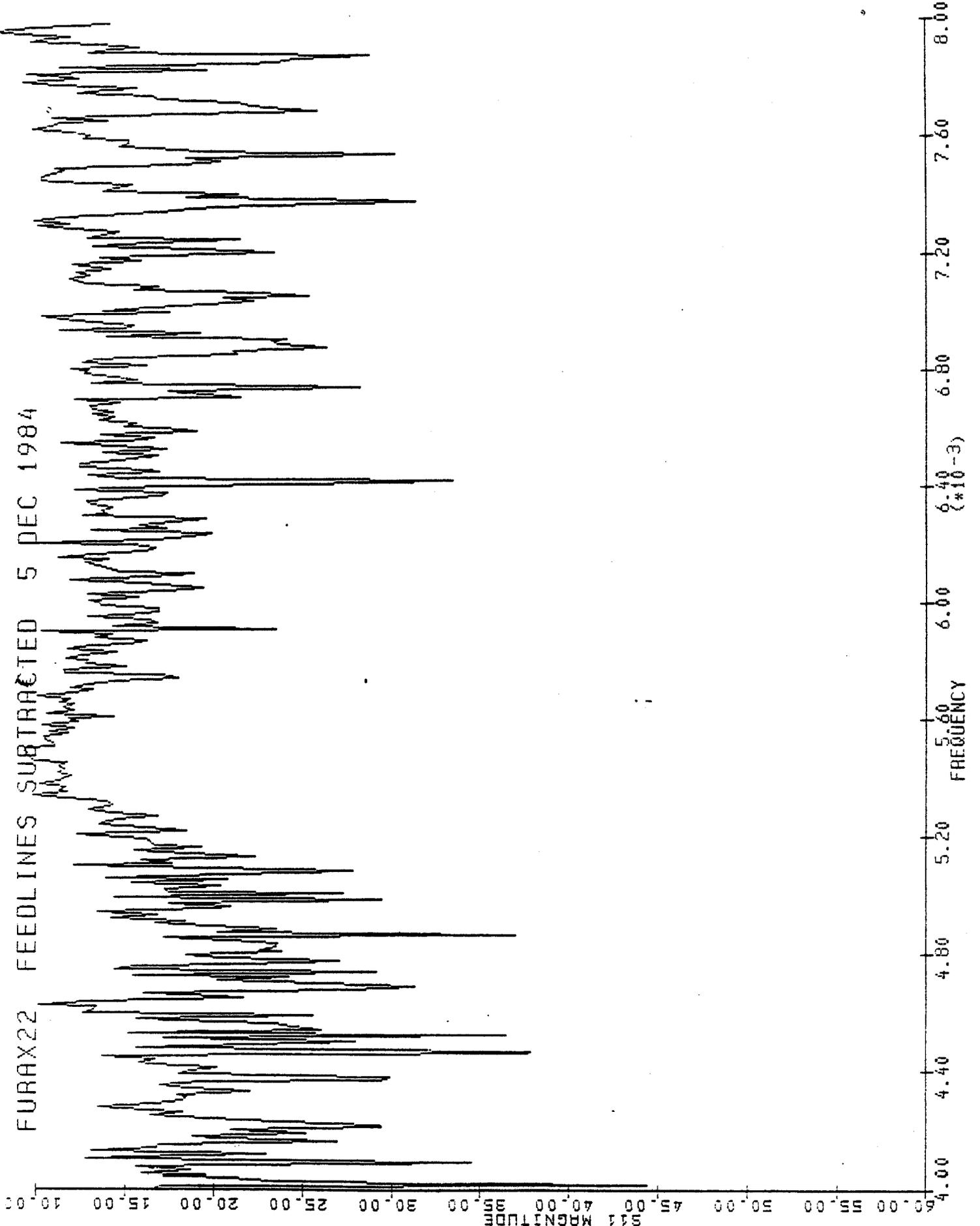
where f is frequency in GHz.

(1) equation 5 from paper by Y. Hoshiko from the Fifth International Cryogenic Engineering Conference.

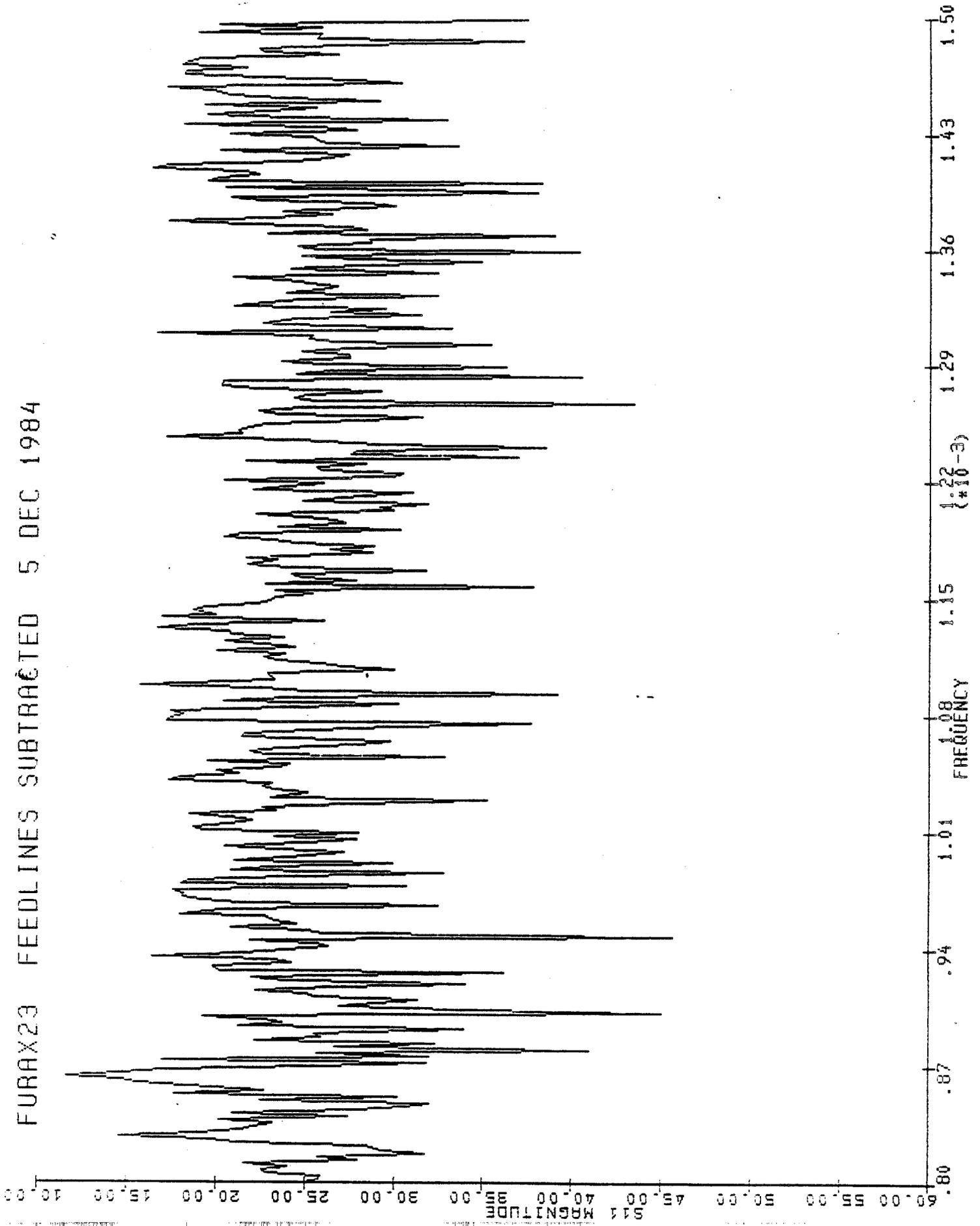
FURAX21 FEEDLINES SUBTRACTED 5 DEC 1984



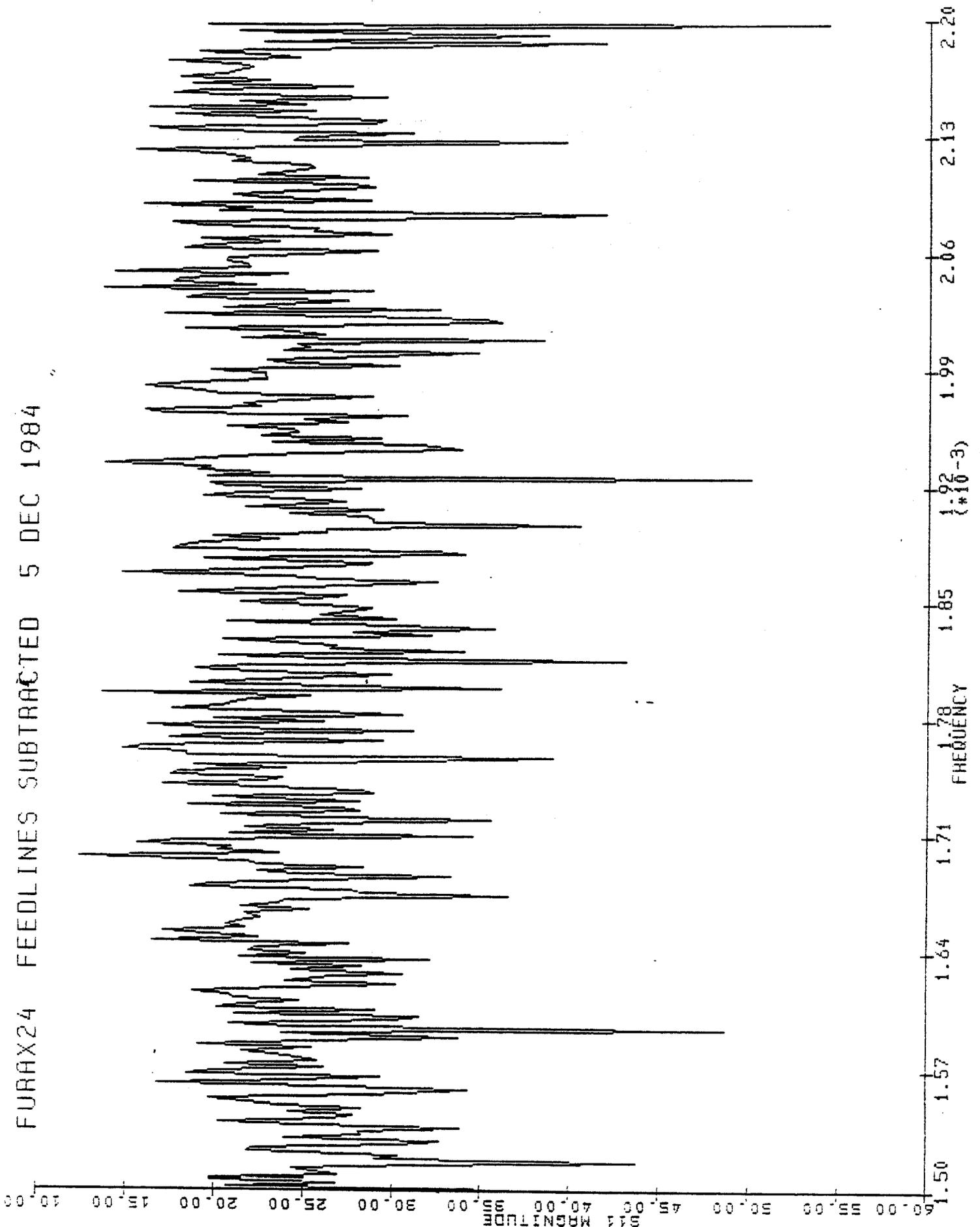
FURAX22 FEEDLINES SUBTRACTED 5 DEC 1984



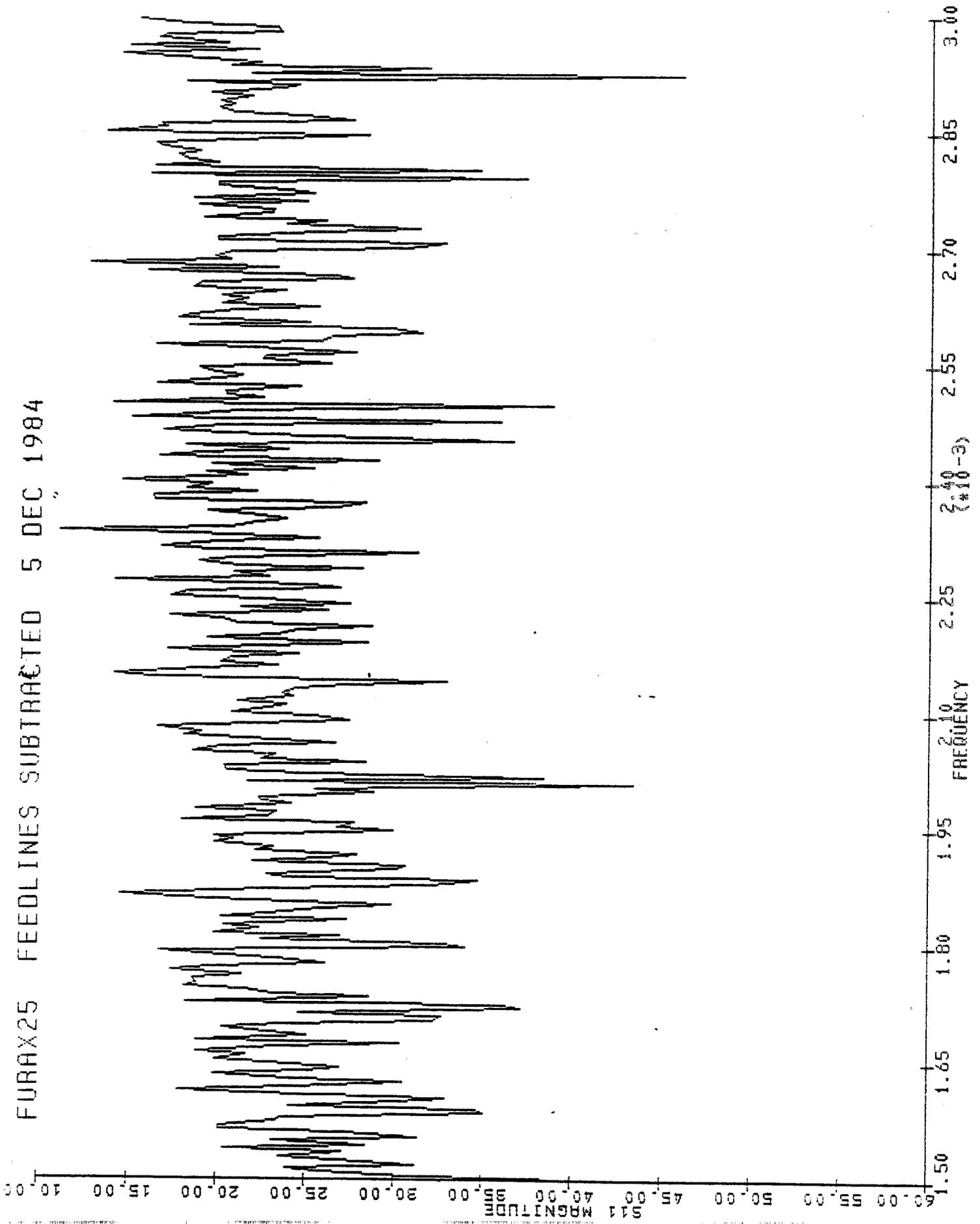
FURAX23 FEEDLINES SUBTRACTED 5 DEC 1984



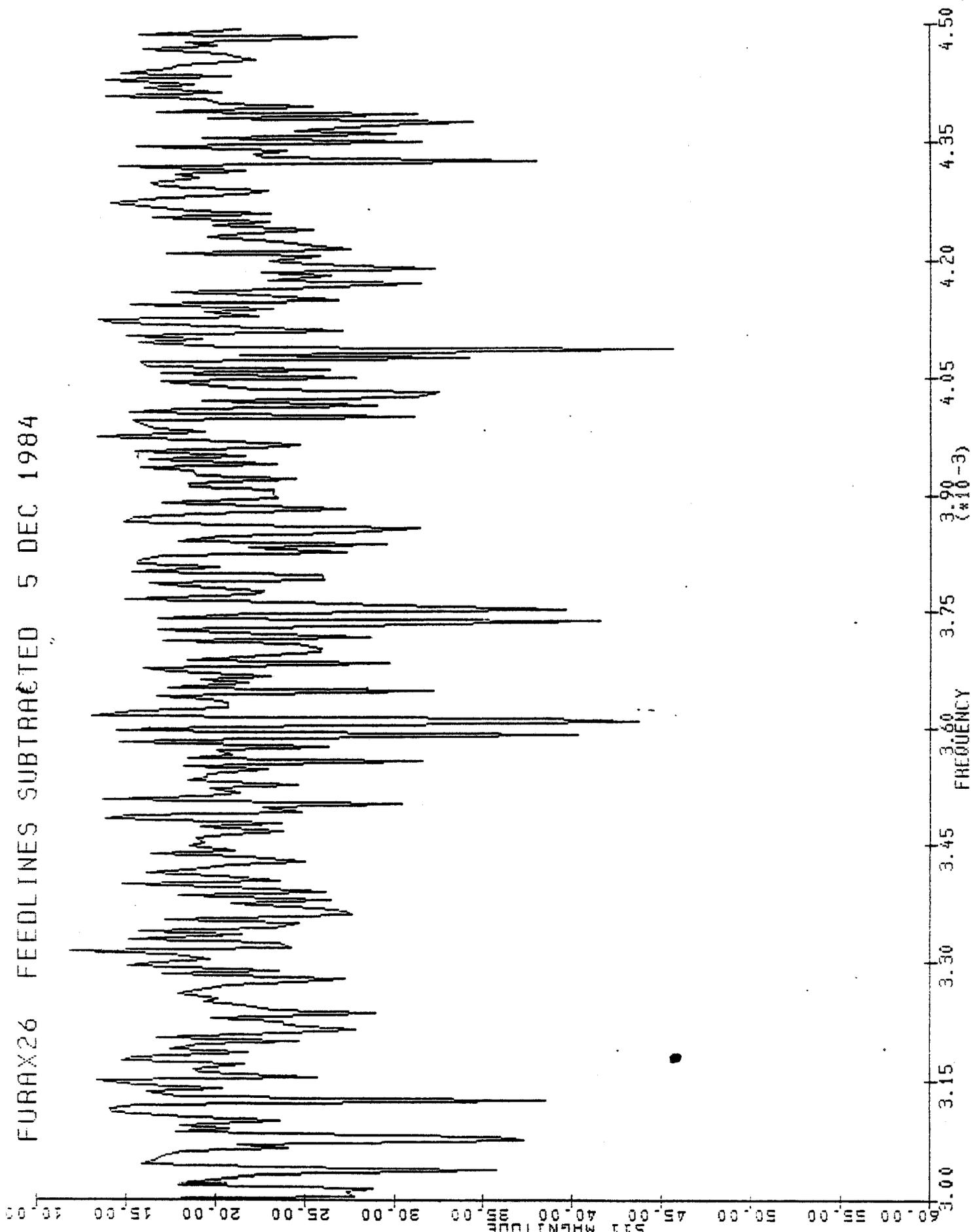
FURAX24 FEEDLINES SUBTRACTED 5 DEC 1984



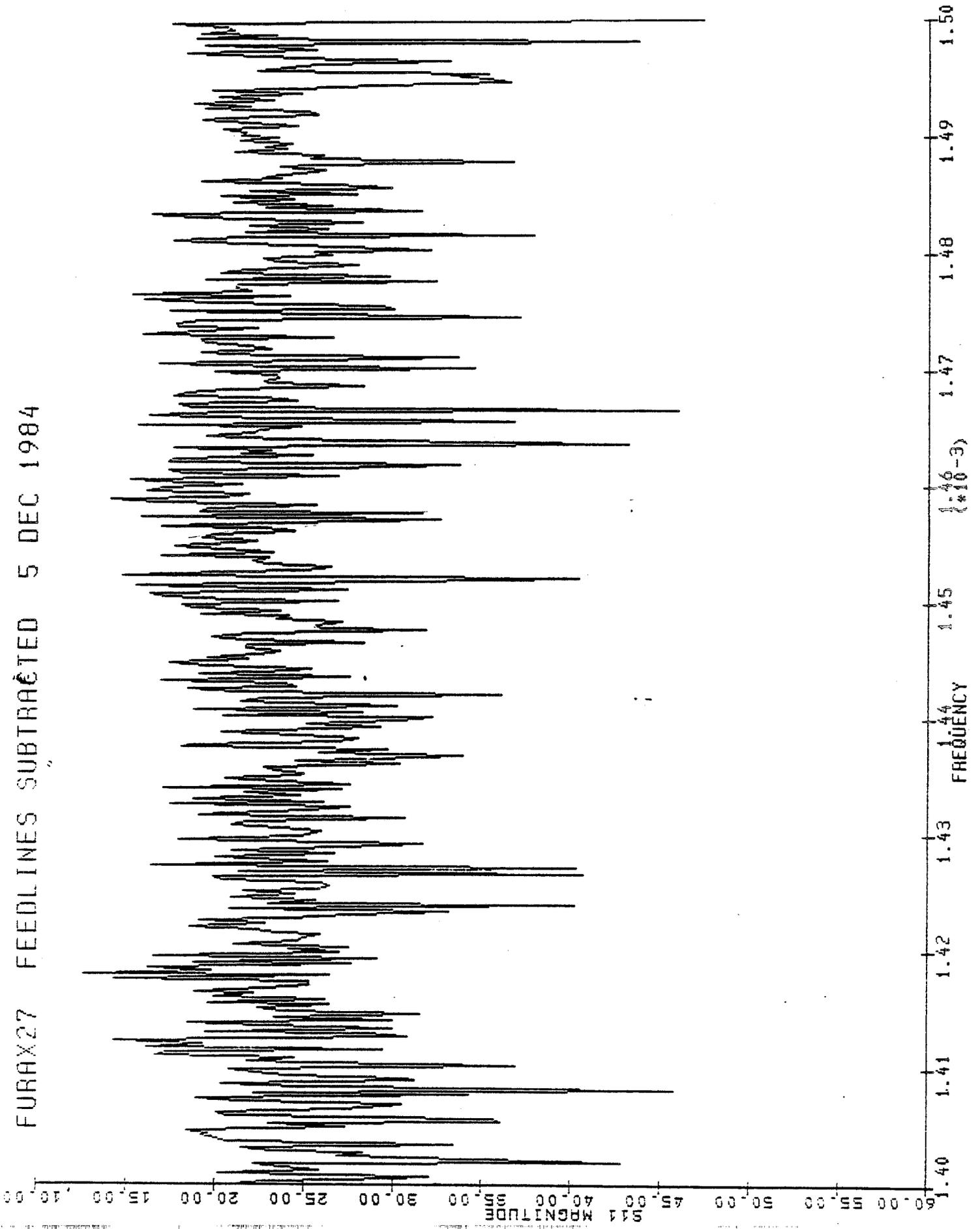
FURAX25 FEEDLINES SUBTRACTED 5 DEC 1984



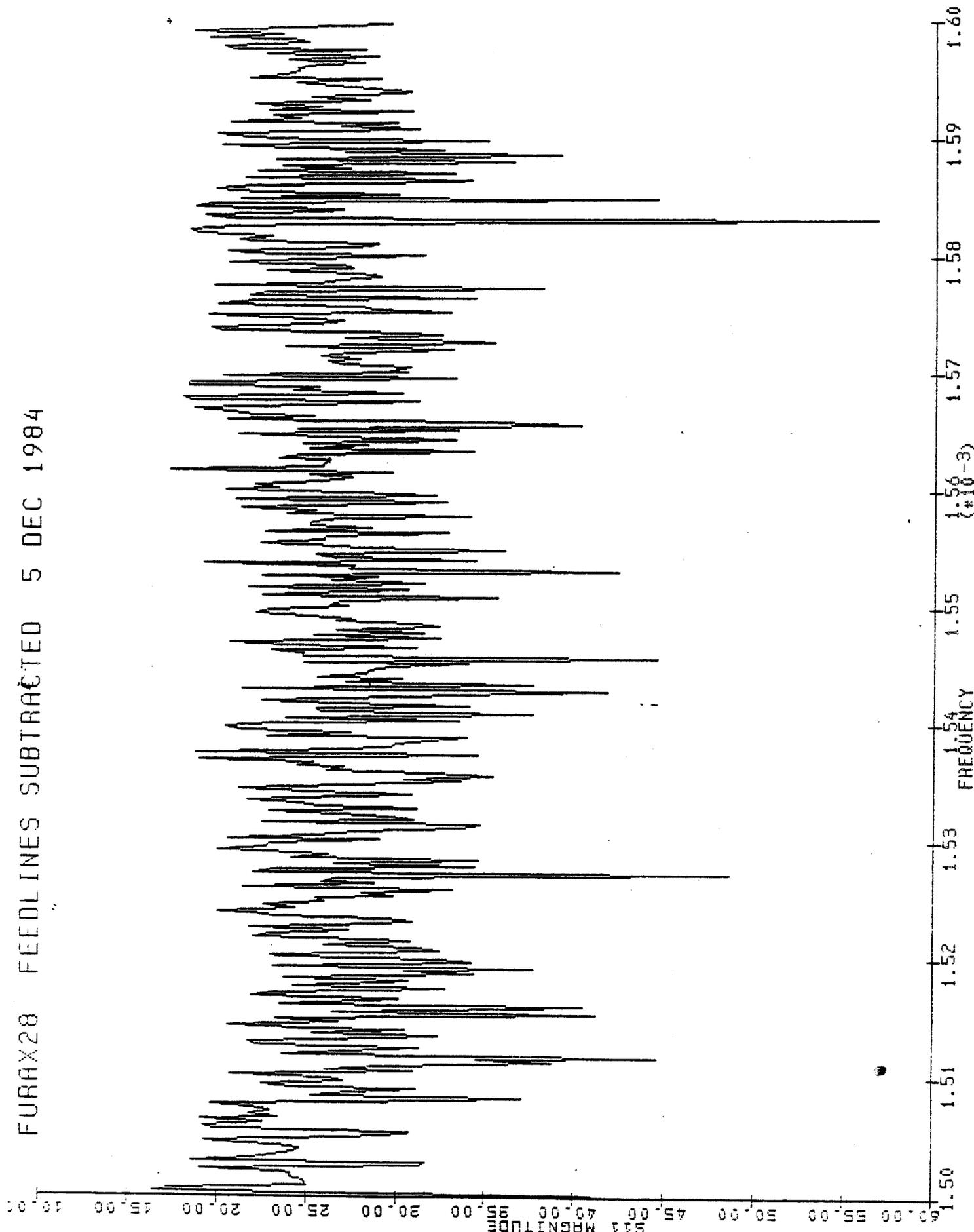
FURAX26 FEEDLINES SUBTRACTED 5 DEC 1984



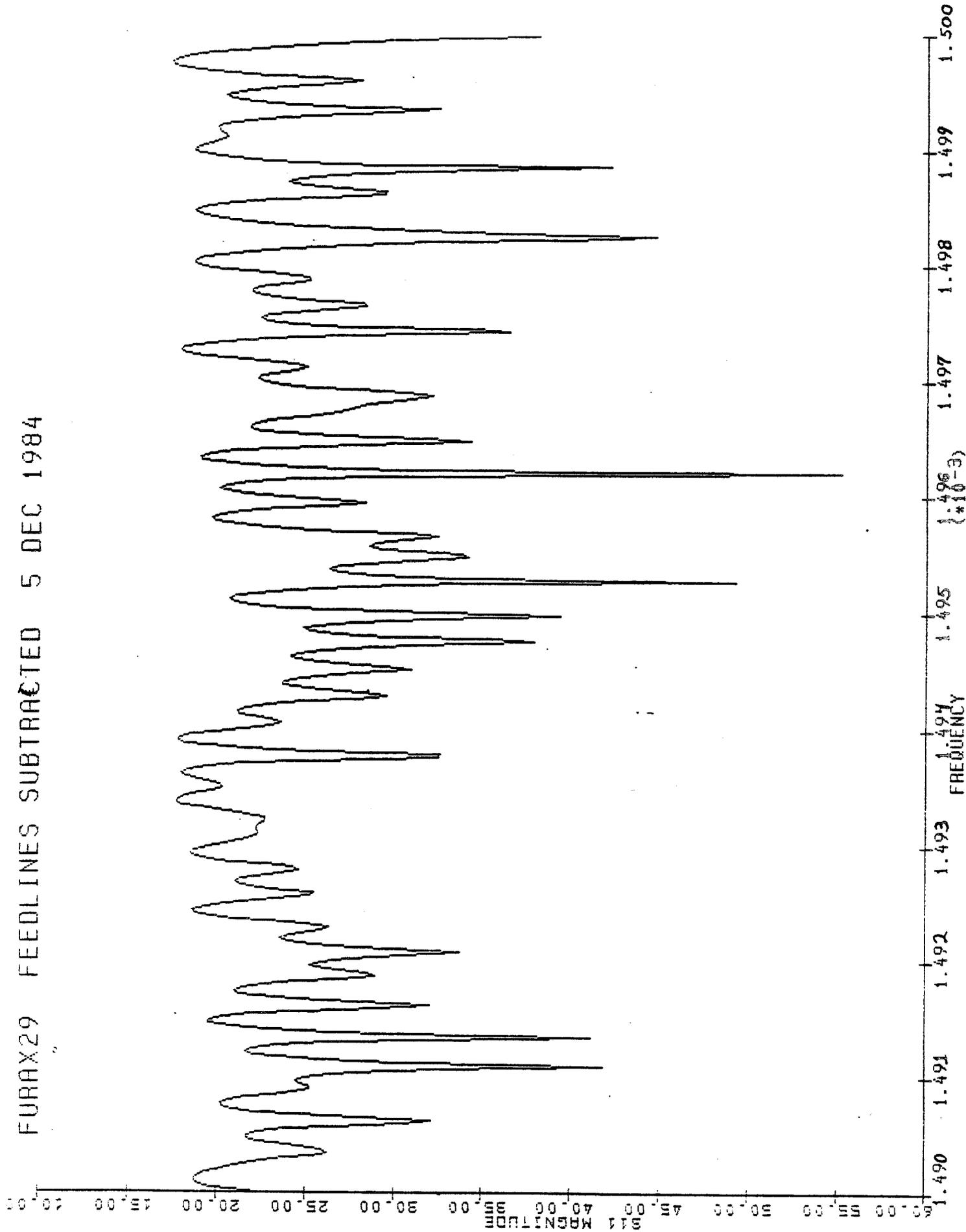
FURAX27 FEEDLINES SUBTRACTED 5 DEC 1984



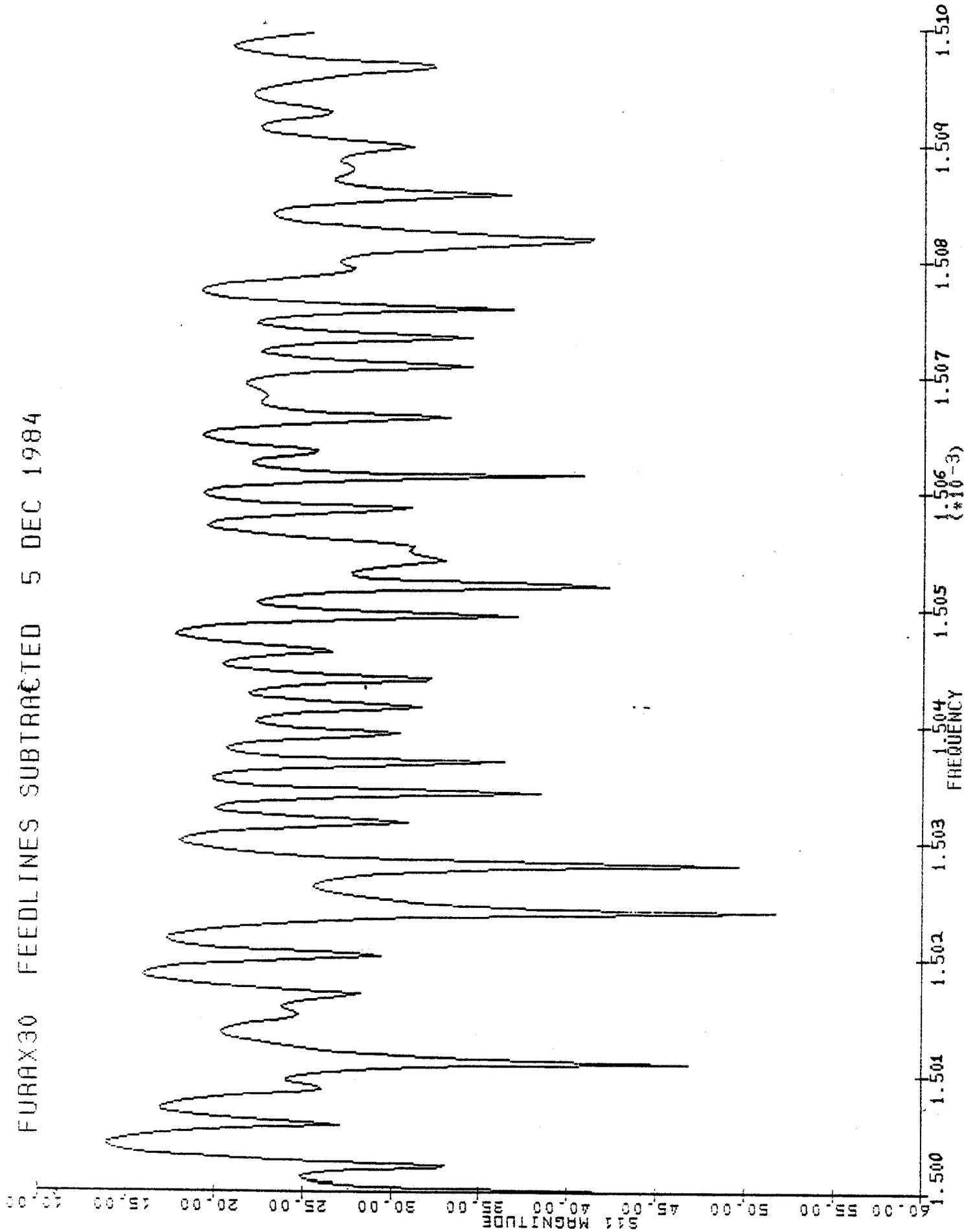
FURAX28 FEEDLINES SUBTRACTED 5 DEC 1984



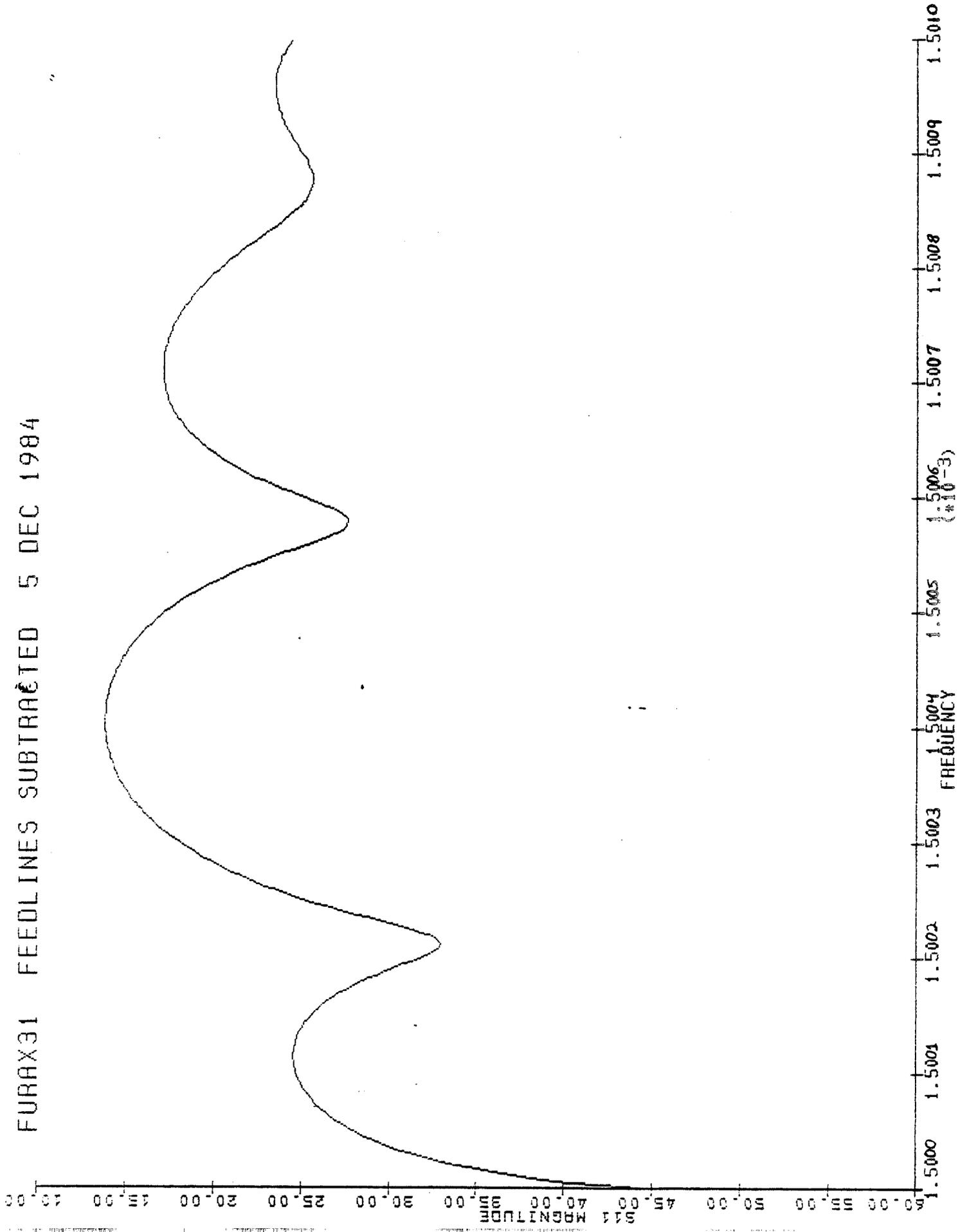
FURAX29 FEEDLINES SUBTRACTED 5 DEC 1984



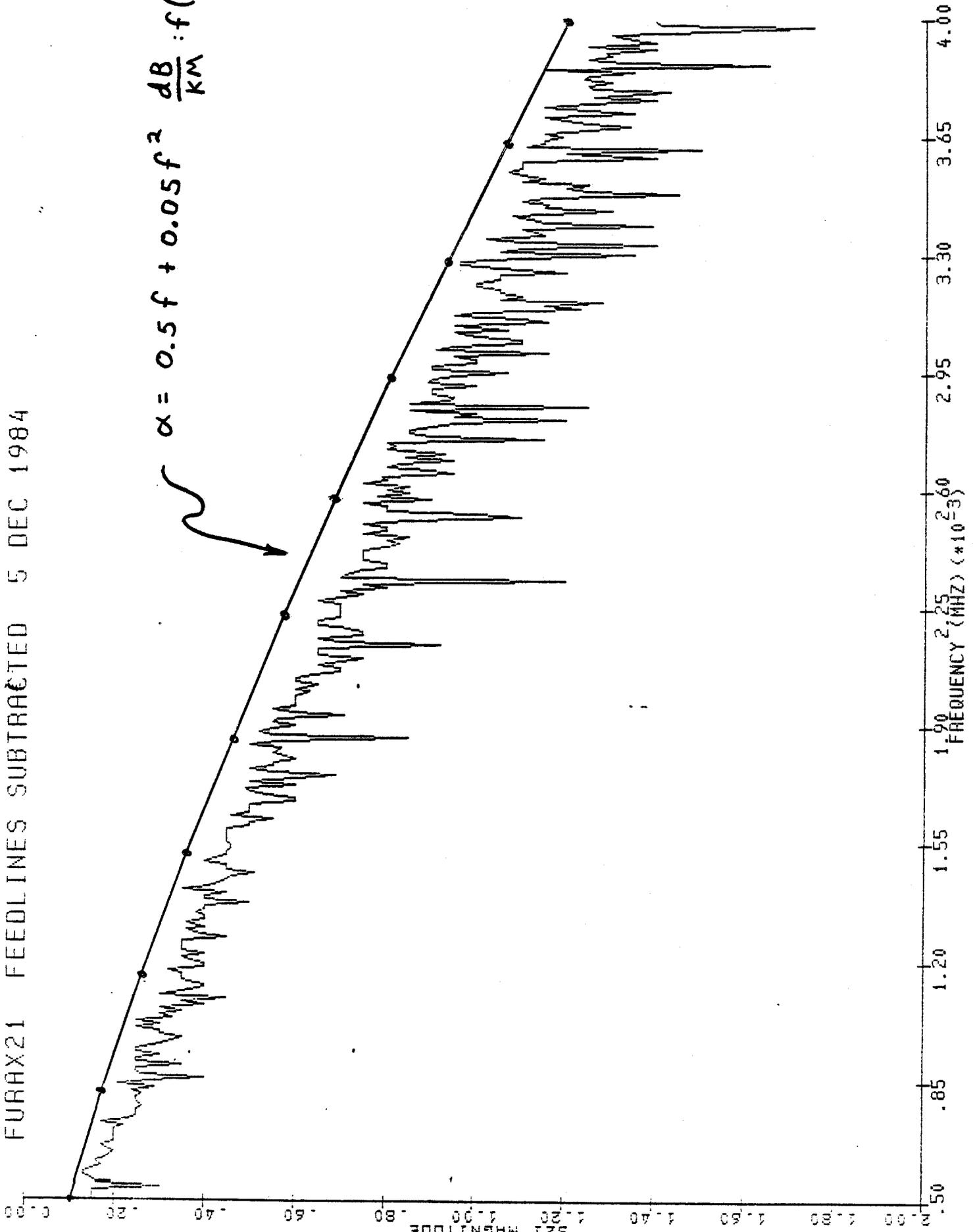
FURAX30 FEEDLINES SUBTRACTED 5 DEC 1984



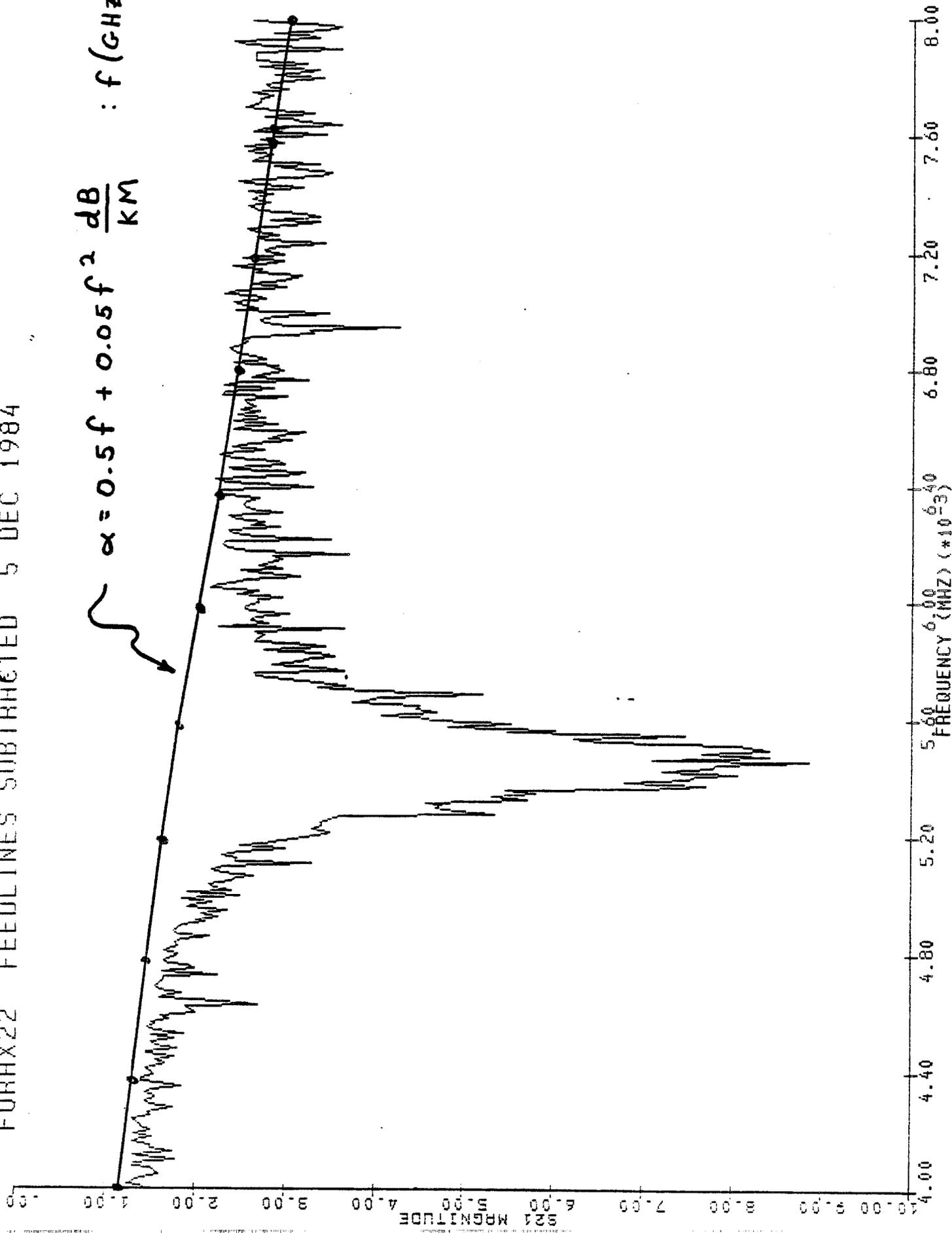
FURAX31 FEEDLINES SUBTRACTED 5 DEC 1984



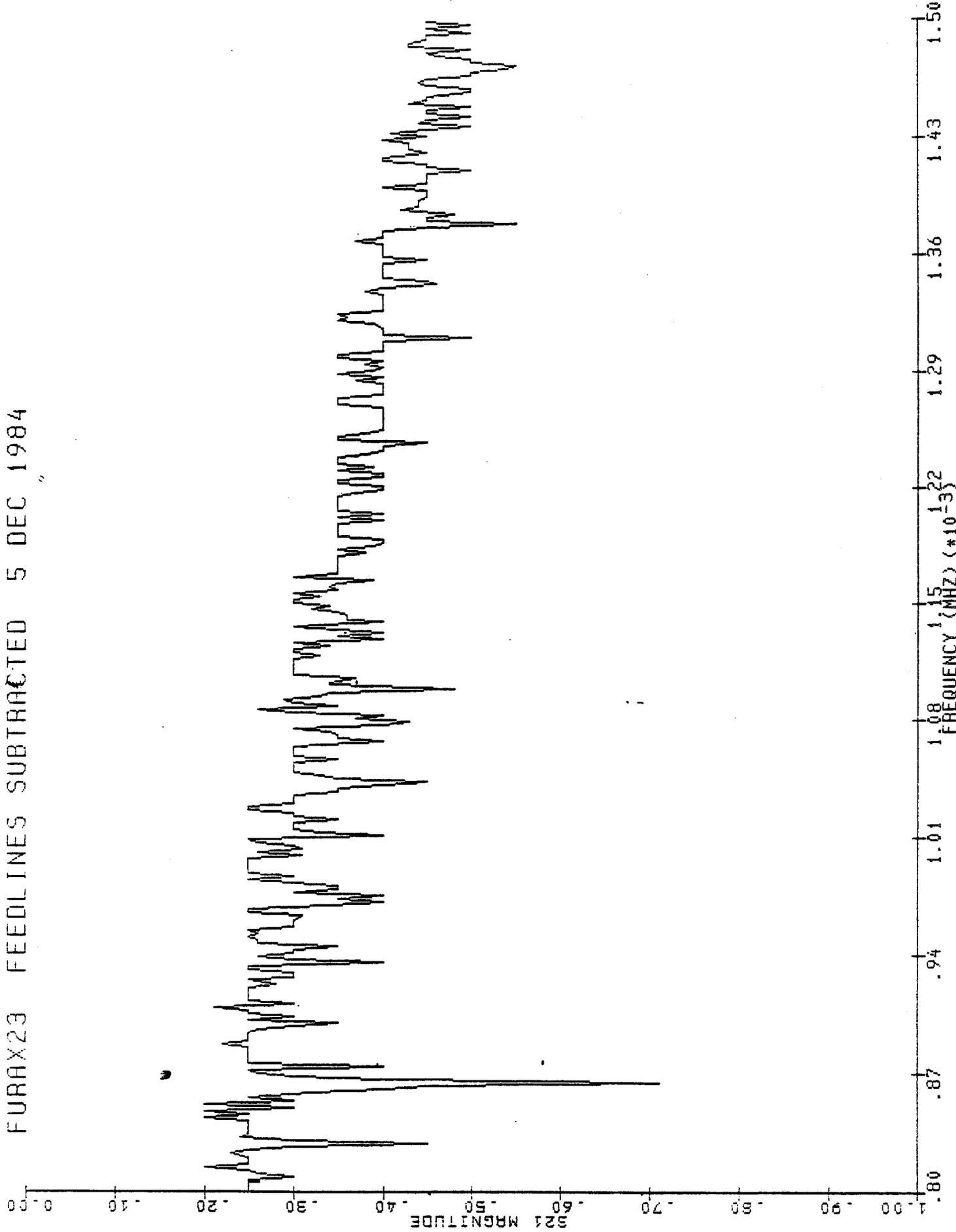
FURAX21 FEEDLINES SUBTRACTED 5 DEC 1984



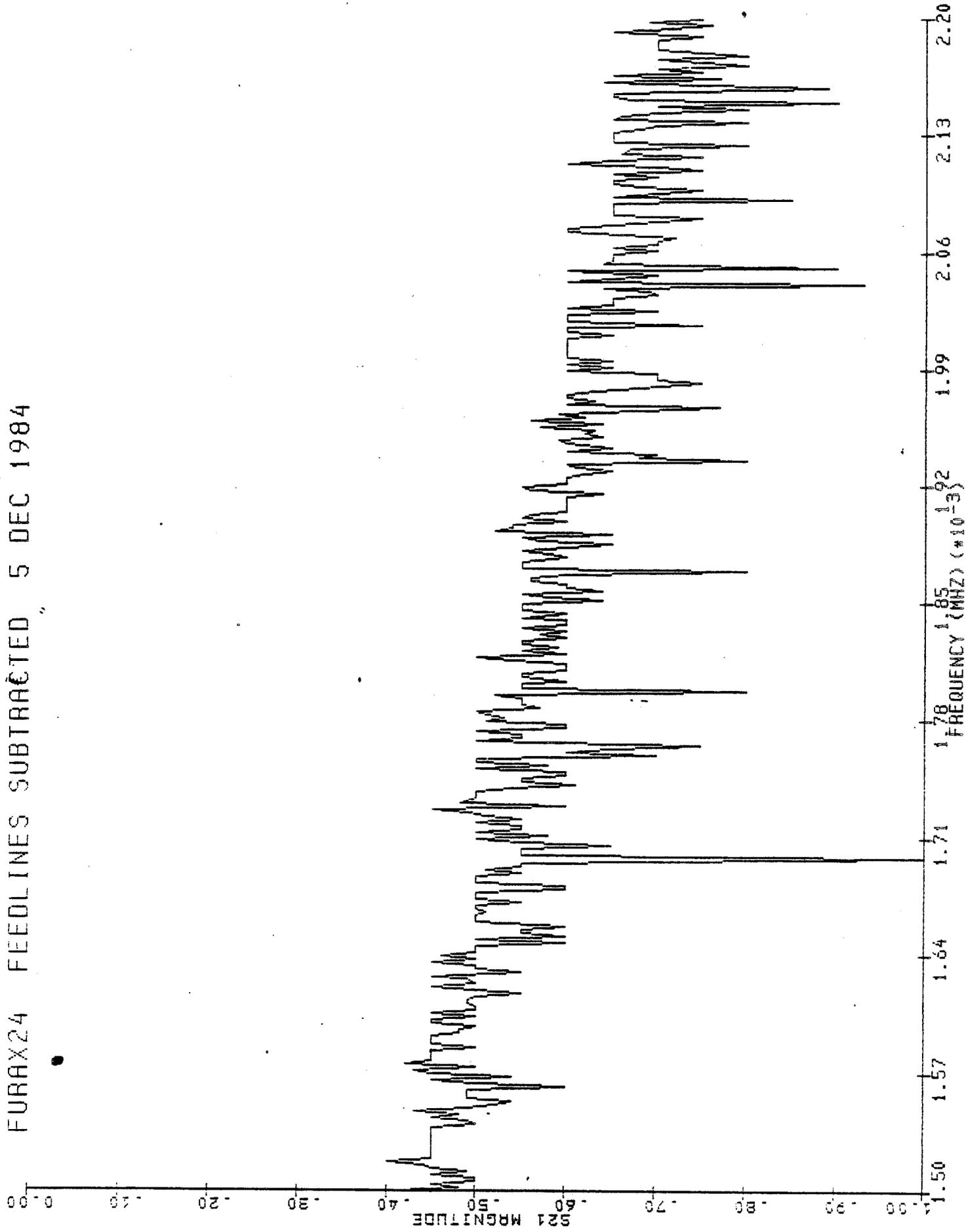
FURAX22 FEEDLINES SUBTRACTED 5 DEC 1984



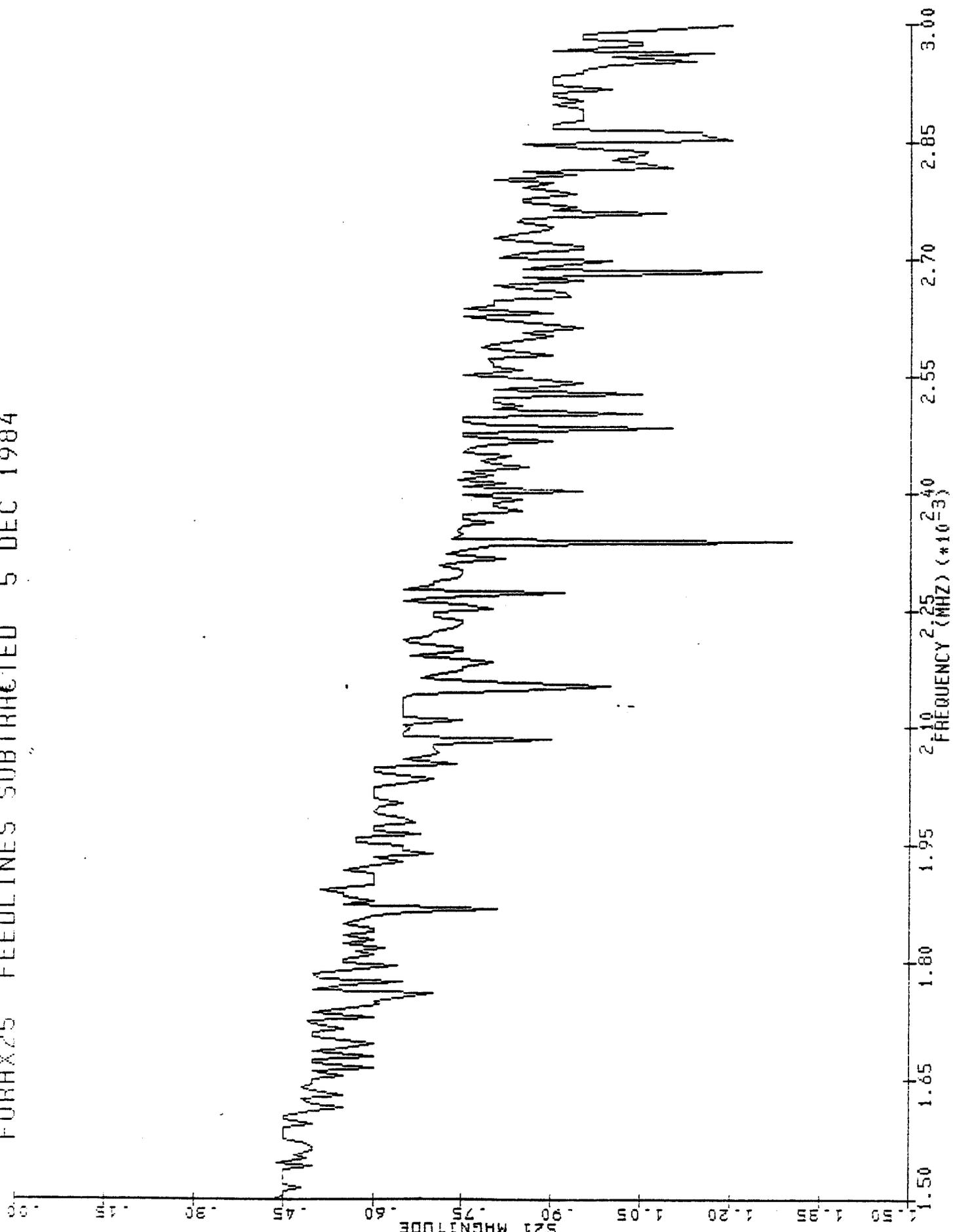
FURAX23 FEEDLINES SUBTRACTED 5 DEC 1984



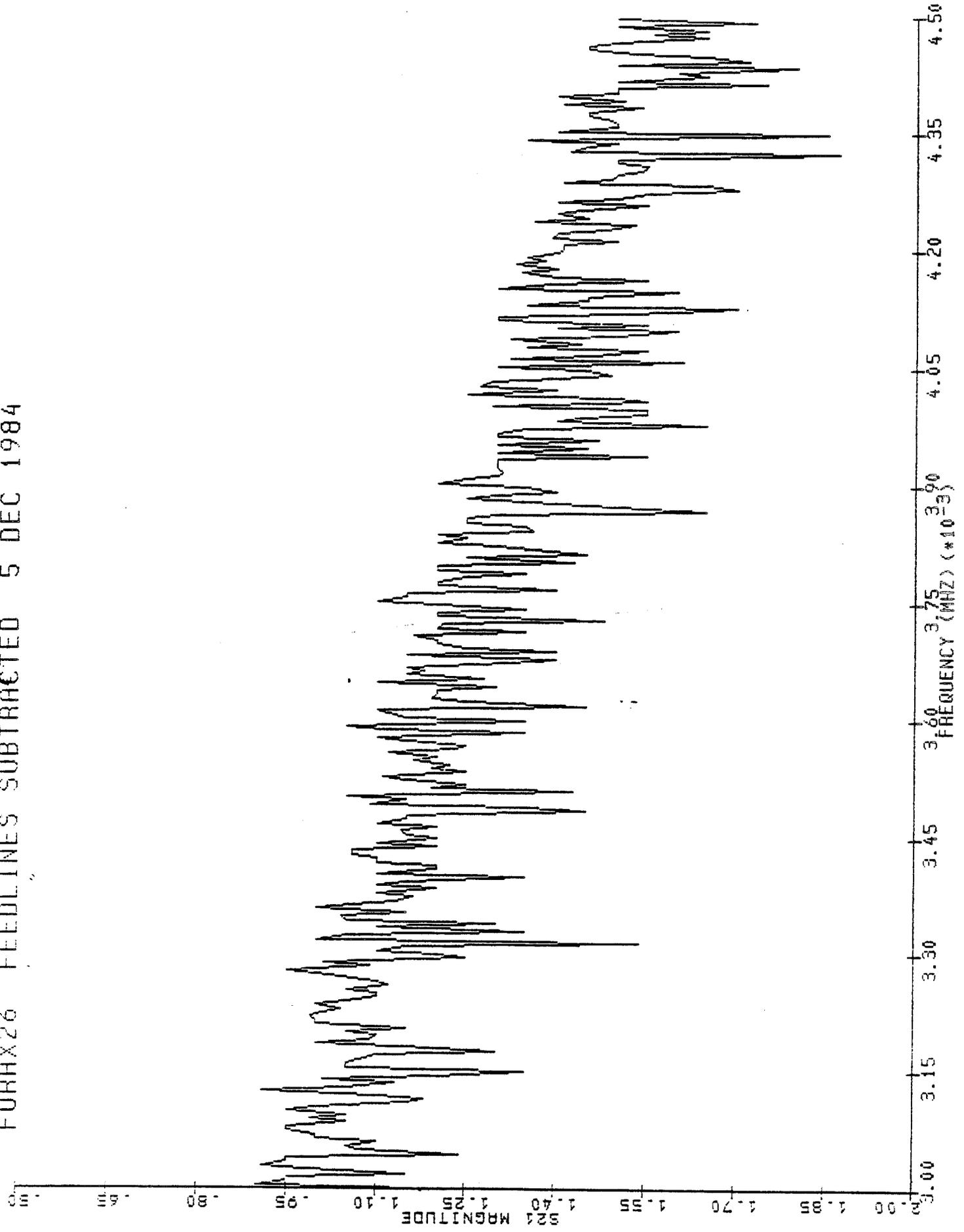
FURAX24 FEEDLINES SUBTRACTED 5 DEC 1984



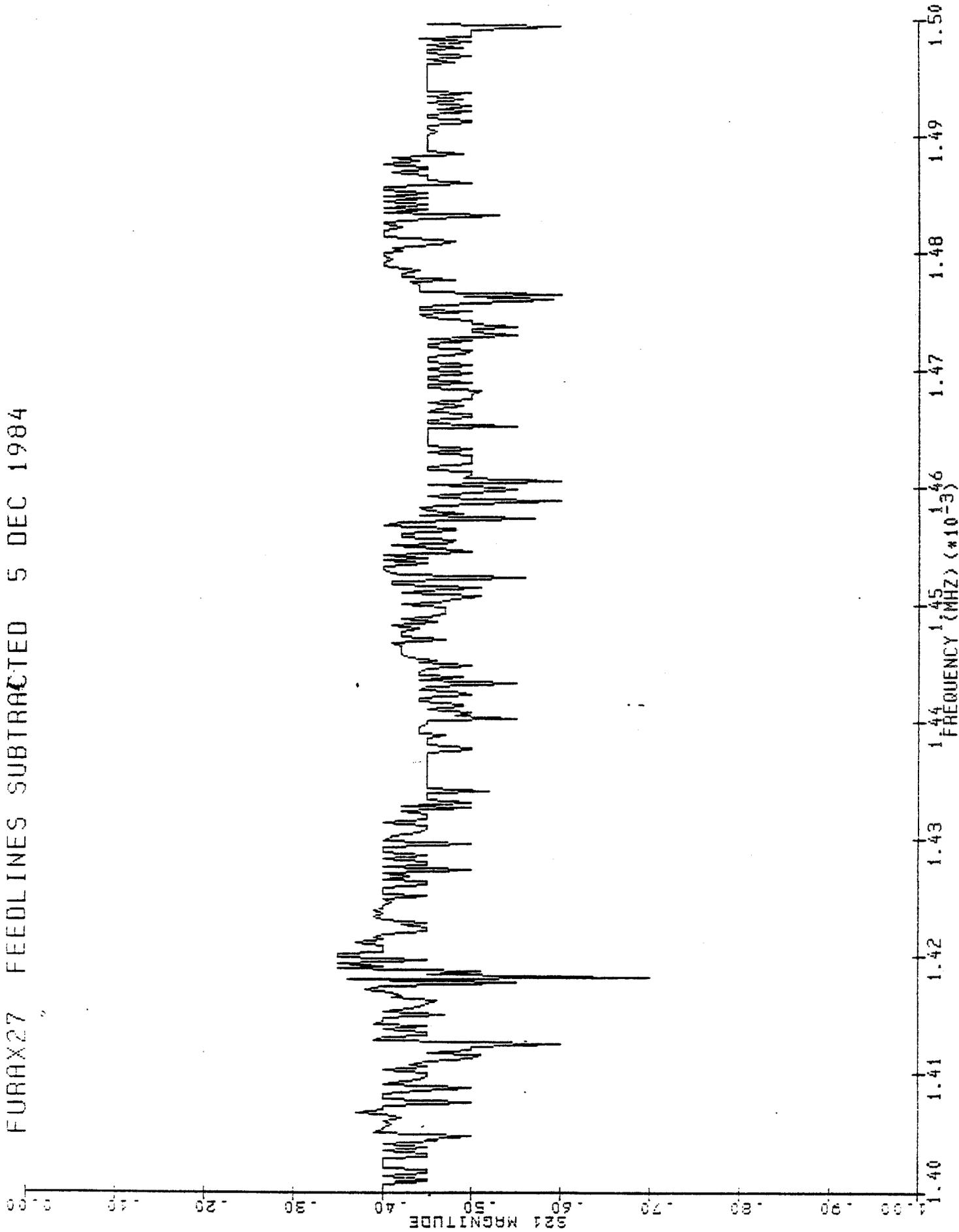
FURAX25 FEEDLINES SUBTRACTED 5 DEC 1984



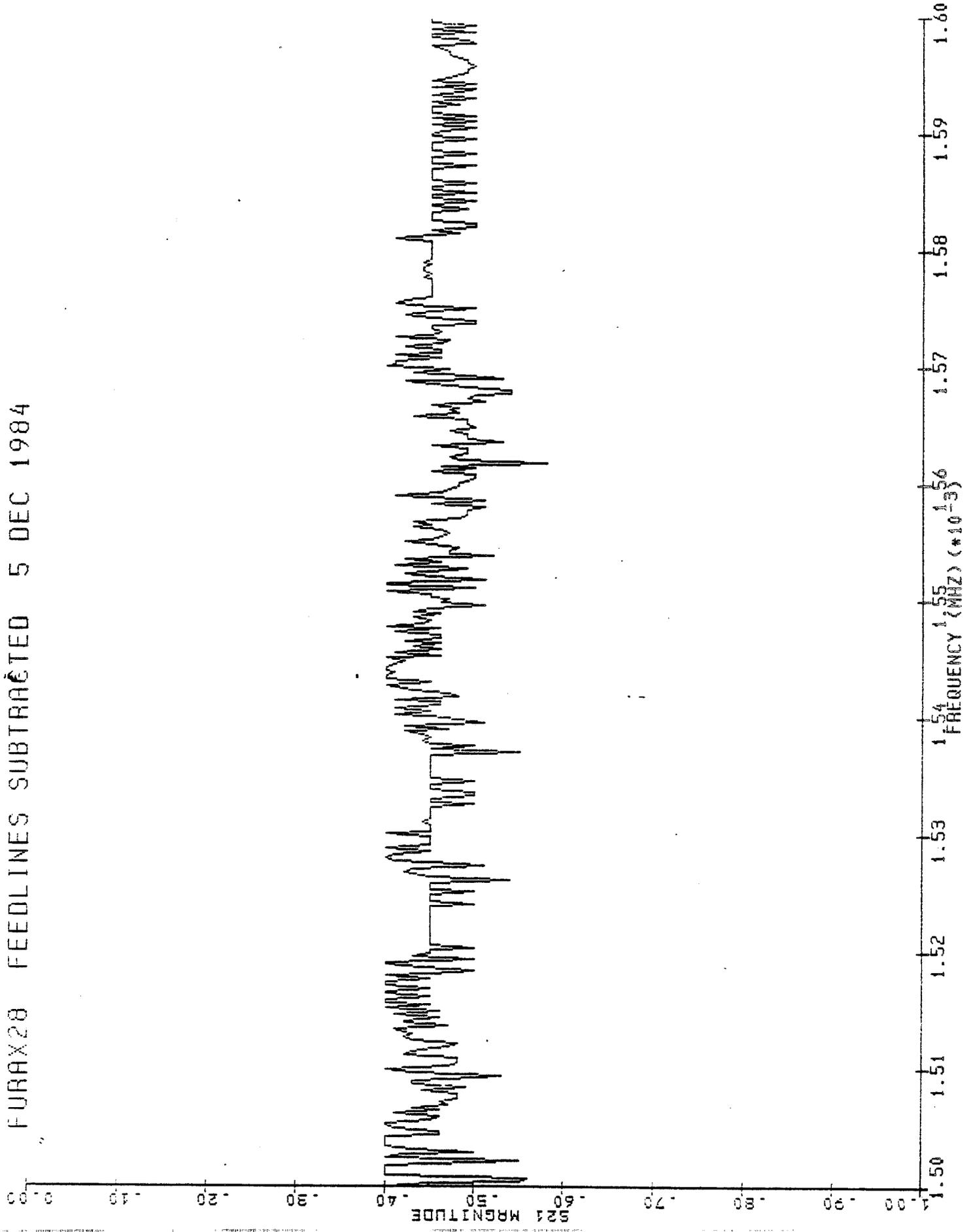
FURAX26 FEEDLINES SUBTRACTED 5 DEC 1984



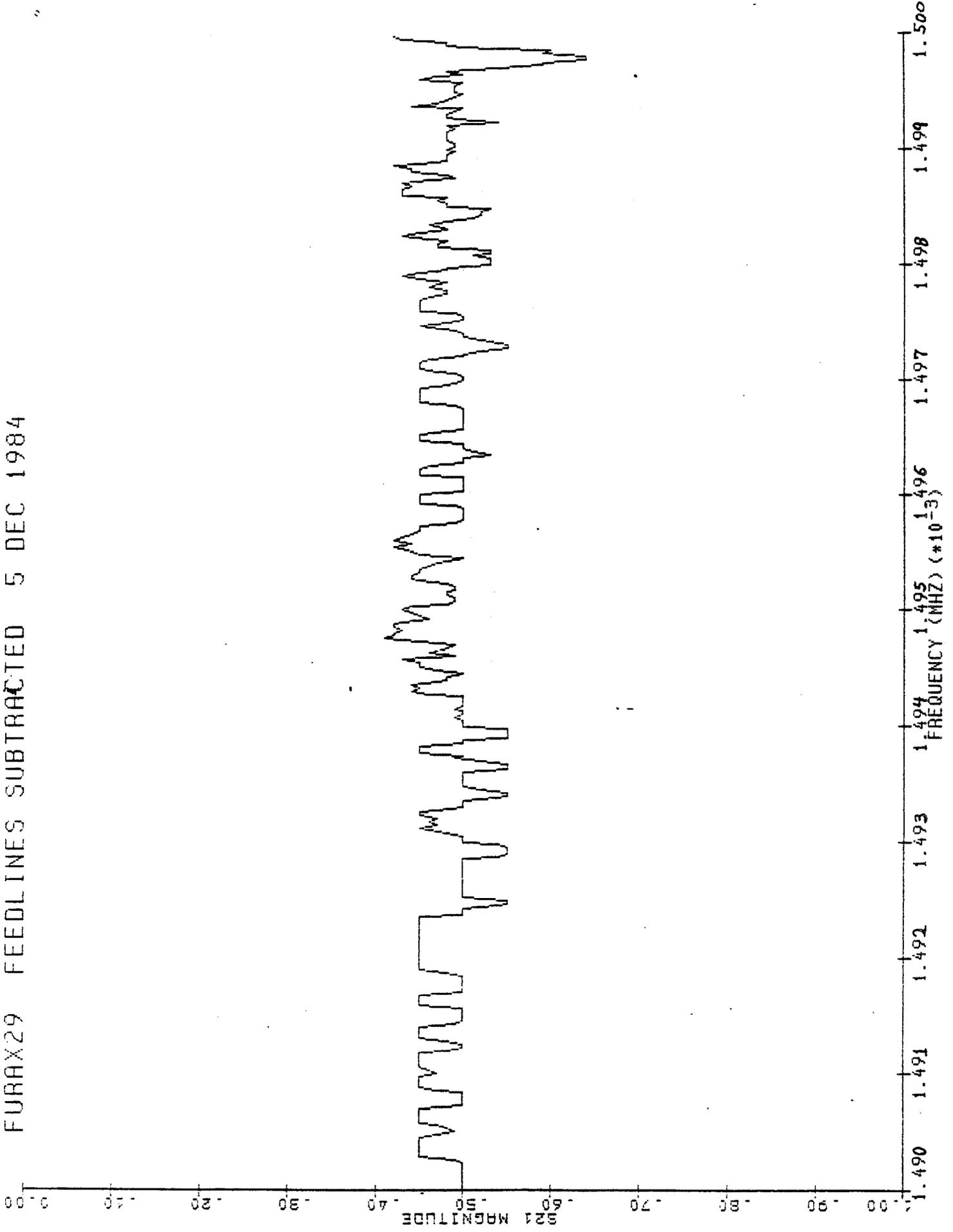
FURAX27 FEEDLINES SUBTRACTED 5 DEC 1984



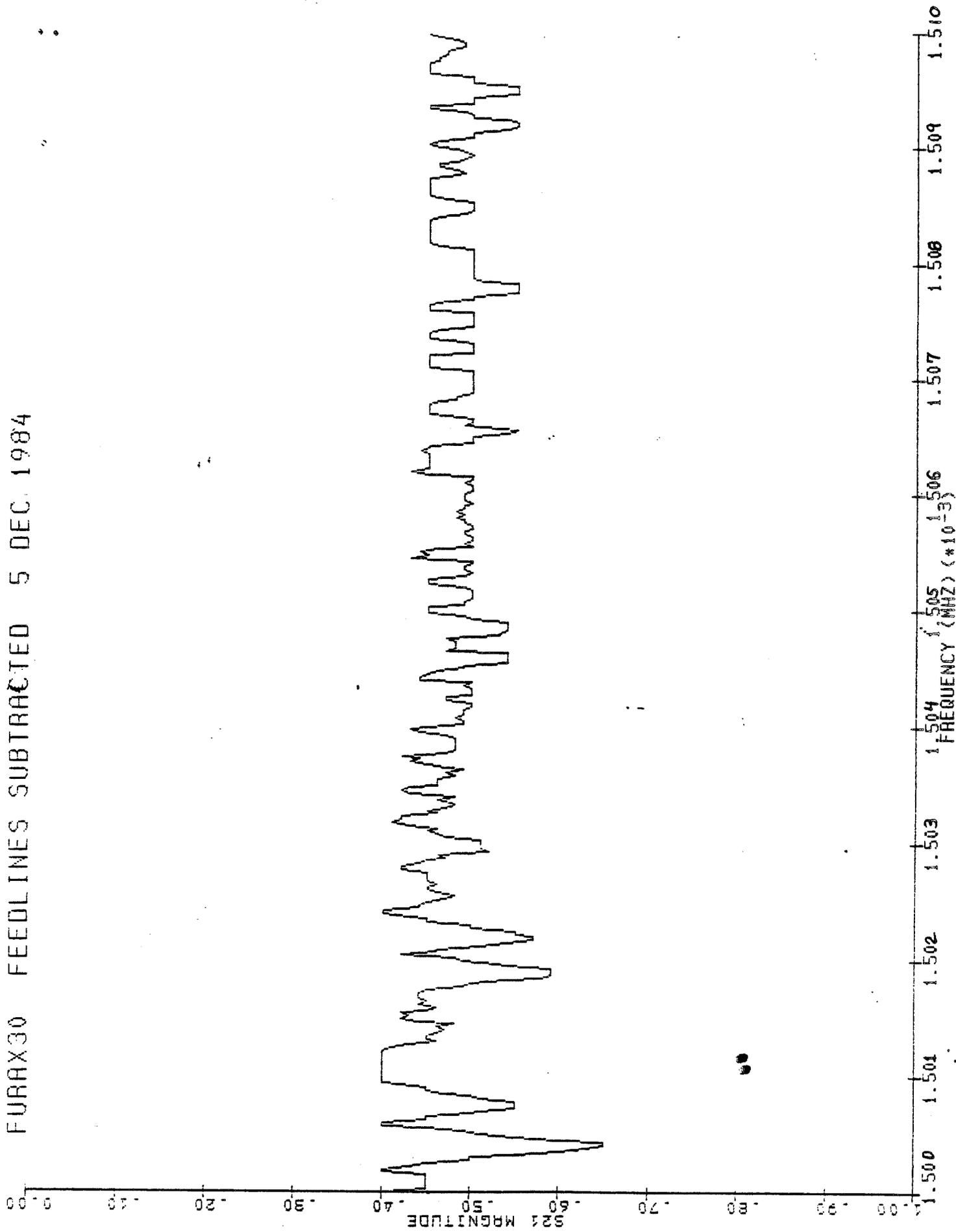
FURAX28 FEEDLINES SUBTRACTED 5 DEC 1984



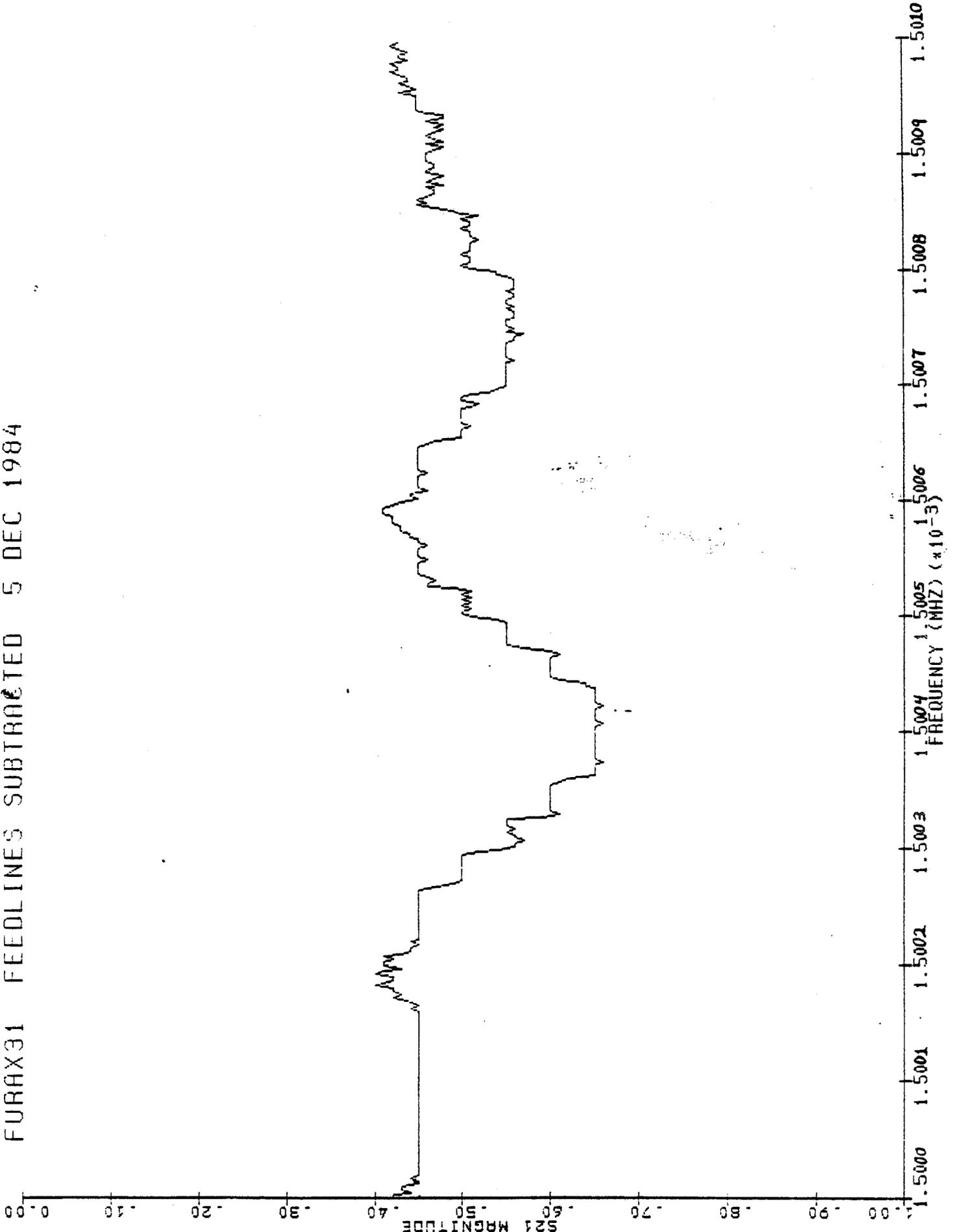
FURAX29 FEEDLINES SUBTRACTED 5 DEC 1984



FURAX30 FEEDLINES SUBTRACTED 5 DEC. 1984



FURAX31 FEEDLINES SUBTRACTED 5 DEC 1984



CONCLUSIONS :

The results of the tests on Furukawa Coax #2 show that the coax performs well in the superconducting state. TDR measurements show an impedance change from 56 Ohms at room temperature to 52 Ohms when superconducting. The major measurable discontinuities are due to connectors. RLC measurements of inductance and capacitance yield values of characteristic impedance very close to the TDR values. The large difference between theoretical and measured warm inductances still needs to be understood. Network analyzer plots of S11 and S21 show some periodic structure but the effects are small for short periods and the major effects are due to end reflections at the connectors. The spikes seen between 800 and 1000 MHz could possibly be due to the circumference of the cable spool. This length of 34 to 41 cm scaled by the velocity factor of the coax yields possible resonances between 250 to 300 MHz or harmonics thereof. Another possibility is that the spikes are due to the discontinuities in the section of cable which runs from the bottom of the spool to the connector at the top of the spool.

The S21 test data agree fairly well with the Hoshiko equation within the limits of measurement and calibration. The slight additional loss may be due to differences in the calibration feedlines as compared to the tested feedlines.

ACKNOWLEDGEMENTS :

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